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A unique guild of Lepidoptera associated with the glacial relict populations of Labrador tea (*Ledum palustre* Linnaeus, 1753) in Central European peatlands (Insecta: Lepidoptera)

K. Spitzer & J. Jaroš

Abstract

The highly specific local guild of nine tyrphobiontic (peat bog specialists) and eight tyrphophile (peat bog affiliates) species of moths (16 species) and only one tyrphobiontic species of butterfly (Lepidoptera) associated with the Labrador tea (*Ledum palustre* Linnaeus, 1753) is a unique phenomenon of peat bogs near the fragmentary southern frontier of the boreal zone in Central Europe. 19 species are tyrphoneutral of wide ecological amplitude. Composition of tyrphobionts and tyrphophiles seems to be a model example of glacial relict peatland Lepidoptera species and their cold-adapted continental subarctic food plant. A similar guild is recorded from subarctic tundra biotopes only. This community of moths and butterflies, which is found only in a few relict isolated peat bogs, is determined and buffered by a unique *Sphagnum* microclimate of postglacial/Holocene peat bogs ("climatic trap") and the highly specific cold-adapted food plants (glacial relicts) represented by the Labrador tea. All such isolated ancient peat bogs with *Ledum palustre* and their Lepidoptera need complete habitat conservation with special respect to hydrological conditions and urgent monitoring of their glacial relict insect community under a possible impact of climatic change.
KEY WORDS: Insecta, Lepidoptera, relict peat bogs, cold-adapted moths, climatic trap, tyrphobionts, tyrphophiles, central Europe.

Una comunidad única de Lepidoptera asociada con las poblaciones relictas glaciares del té de Labrador (*Ledum palustre* Linnaeus, 1753) en las turberas de Europa Central (Insecta: Lepidoptera)

Resumen

La comunidad local muy específica de nueve tirfobiónticos (especialistas en la turba) y ocho especies tirfófilas (que prefieren la turba) de polillas (16 especies) y sólo una especie de mariposa tirfobióntica (Lepidoptera) relacionadas con el té de Labrador (*Ledum palustre* Linnaeus, 1753) constituye un fenómeno único de las turberas en la frontera sur fragmentaria de la zona boreal en Europa Central. 19 especies son tirfoneutrales en una adaptación ecológica amplia. La composición de tirfobiontes y tirfófilos parece ser un ejemplo modélico de especies de Lepidoptera de las turberas glaciales relictas y su planta nutricia subártica adaptada al frío. Una comunidad similar se conoce en biotopos de tundra subárctica solamente. Esta comunidad de polillas y mariposas, que se encuentra solamente en algunas turbas relictas aisladas, es determinada y protegida por un microclima único de *Sphagnum* las turberas postglaciales/Holoceno ("Trampa climática") y las plantas nutricis muy específicas adaptadas al frío (fríos relictos) representada por el té de Labrador. Todas las turberas antiguas aisladas con *Ledum palustre* y sus Lepidoptera necesitan protección completa del medio ambiente y de hábitat con especial respeto a las condiciones de hidrológicas y una observación urgente de su comunidad glaciar de insectos bajo un impacto de un posible cambio climático.
PALABRAS CLAVE: Insecta, Lepidoptera, turba relicta, polillas adaptadas al frío, trampa climática, tirfobiontes, tirfófilos, Europa central.

Introduction

The Labrador tea (*Ledum palustre* L. (s. lat.)) is a cold-adapted boreal/subarctic low shrub of Holarctic distribution (see e.g. TOLMATCHEV & JURTZEV, 1980; PANOVA *et al*., 2003; AIKEN *et al*., 2007). The southern part of the geographic range of *Ledum* (genus related to *Rhododendron*) is fragmented in boreal and temperate Eurasia and northern America forming communities within the highly isolated paleorefugia of continental acid *Sphagnum* peat bogs (SPITZER & DANKS, 2006) - Figs 1 and 2. Outside peatlands, rare and single occurrences of *Ledum palustre* are recorded also from several types of cold acid sandstone biotopes with specific microclimate, covered by fragmentary *Sphagnum* moss habitats, associated with some cold-adapted arthropod communities as well, but very few specific Lepidoptera (cf. HÄRTEL *et al*., 2007; RŮŽIČKA, 2011). It seems to be evident that tyrphobiontic moths are not safely known from sandstone *Ledum* habitats directly, but recorded mostly from adjacent small peat bogs of some sandstone areas (cf. VÁVRA, 2000).

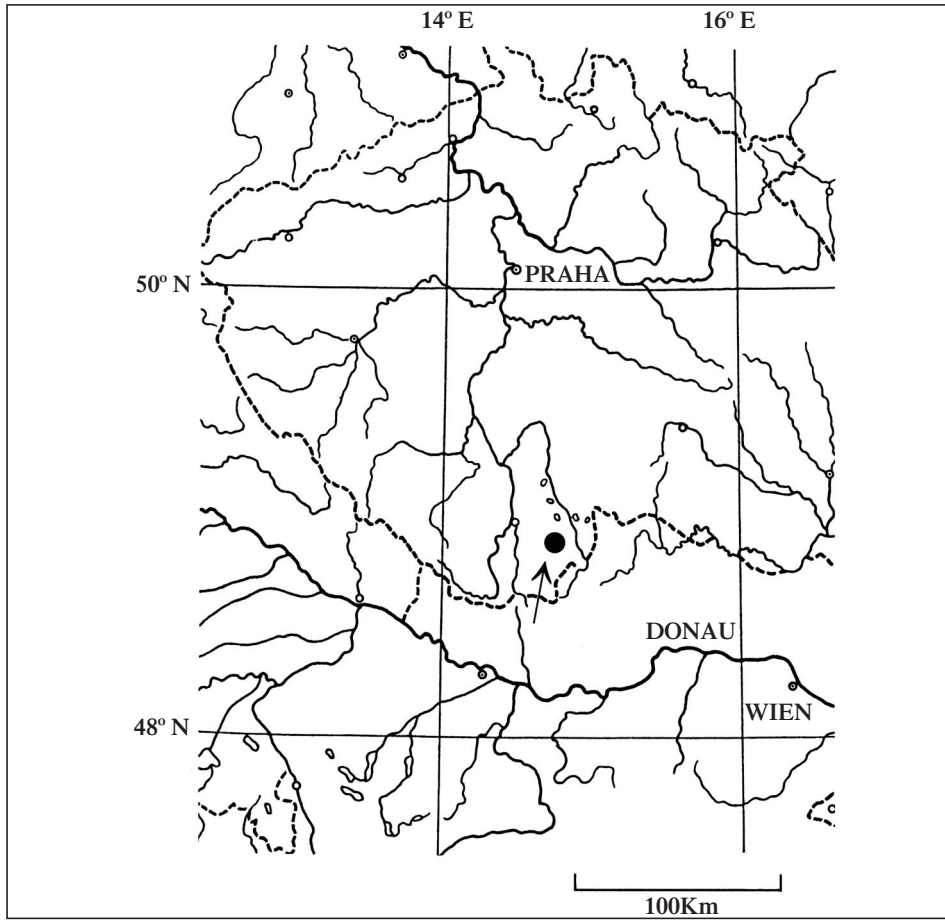

Fig. 1.– Geographical position of the Červené blato bog in the Třeboň Basin (Central Europe) with isolated population of Labrador tea (*Ledum palustre*).

All large fragments of central European communities of *Ledum palustre* are closely associated with ancient *Sphagnum* peatlands only (cf. NEUHÄUSL, 1959, 1972; BŘEZINA, 1975; KRISAI & SCHMIDT, 1983; SPITZER & JAROŠ, 1993) under *Sphagnum* mediated strong microclimatic buffering of bog vegetation and insect communities (SPITZER & DANKS, 2006; TURLURE *et al*., 2009, 2010; SWENGEL & SWENGEL, 2010, 2011; LOZAN *et al*., 2012). Such *Ledum palustre* complex is classified under the characteristic isolated community of *Pino rotundatae-Sphagnetum ledetosum* which association is endemic to Central Europe with dominant local pine tree *Pinus rotundata* Link (BŘEZINA, 1975; JANKOVSKÁ, 1980) - cf. Fig. 2. Here, the largest *Ledum* biotope is the Červené blato bog characterized by a complete unique guild (cf. for guild terminology e.g. WILSON, 1999) of stenotopic "glacial relict" Lepidoptera. This guild is very close in species composition and structure to that of northern *Ledum* habitats (cf. KROGERUS, 1960). The highly isolated central European *Ledum* peat bogs are situated mostly in South Bohemia with the model example of the largest reserve Červené blato bog near Třeboň (SPITZER & JAROŠ, 1993, 2002) - Figs 1 and 2. It is the best investigated *Ledum* locality in Central Europe (cf. KVĚT *et al*., 2002 - MAB UNESCO Reserve of the Třeboň Basin). The Lepidoptera community of the Červené blato bog has been investigated for 40 years, with larvae and adults collected for identification and rearing (SPITZER & JAROŠ, 1993; LOZAN *et al*., 2012 and JAROŠ & SPITZER unpublished notes). The aims of our *Ledum* study are:

1. Description and ecological classification of species composition and guild structure of moths and butterflies associated with *Ledum palustre* of the paleorefugial Červené blato bog.
2. Comparison of the guild structure with similar *Ledum* communities in boreal/subarctic Europe.
3. Discussion of peat bog environments, the "climatic trap" of *Sphagnum* bog coldlands (TALLIS, 1991; VAN BREEMEN, 1995; TURLURE *et al*., 2009, 2010) and implement our data and conclusions for lepidopterological aspects of relict *Ledum* habitats conservation.

Site description and methods

The Reserve Červené blato bog (48º 52' N, 14º 48' E, 472 m alt.), 331 ha and adjacent small destructed peatlands in the Třeboň Basin, southeast Bohemia (Czechia) is the largest locality for *Ledum palustre* in Central Europe (for detailed locality description and vegetation map, see SPITZER & JAROŠ, 1993; SPITZER *et al*., 1999) - Figs 1 and 2. The nearest similar *Ledum* localities are situated in north-eastern Germany (see e.g. PEUS, 1932). Unfortunately most *Ledum* localities in central Europe are extremely small and/or demaged by destruction of hydrological conditions and by fire (including the second largest peat bog Žofinka in the Třeboň Basin - cf. KUČEROVÁ *et al*., 2008). The complete fauna of Lepidoptera (adults and larvae) here has been investigated by the authors for the past 40 years. The most intensive collecting of larvae of Lepidoptera was carried out from 2000 to 2011, with special reference to the basic glacial relict food plants *Ledum palustre* L. and *Vaccinium uliginosum* L. (Ericaceae) (cf. Table I). Numerous larvae of Lepidoptera were collected during our studies of their parasitoids (LOZAN *et al*., 2012). All larvae were collected by sweeping net and searching (e.g. mining larvae) between May and September. All specimens were identified (some species after rearing to adults).

Results

Species composition of Lepidoptera feeding on *Ledum palustre* in the Červené blato bog is summarized in Table I. All the species feeding on *Ledum*, either obligate or facultative, can complete their life cycles in such association. All the butterflies and moths are characterized with respect to food plants and the "tyrpho-classification" of tyrphobionts (bog specialists), tyrphophiles (bog affiliates) and tyrphoneutrals (SPITZER & DANKS, 2006). All relict tyrphobiontic species associated with *Ledum palustre* are either *Ledum* monophagous (five species) or oligophagous feeding also on boreal

Vaccinium uliginosum (four species). In other words, both groups of species feed on relict cold-adapted food plants. Tyrphophiles are usually polyphagous, feeding mostly on *Vaccinium* spp. and several other woody plants and/or herbs. All tyrphoneutral species (generalists) of wide ecological amplitude are usually polyphagous and rarely feed solely on *Ledum palustre* (Table I). There is, however, significant evidence of a close association of tyrphobionts to the relict food plants *Ledum palustre* or/and alternative *Vaccinium uliginosum*. The number of food plants of some tyrphophiles is much higher and the species are widely distributed outside the bog as well.

Discussion and conclusions

Sphagnum mosses built the bog environment with its unique cool waterlogged and acid edaphic conditions. Highly specific conditions (in particular cold and humid micro- mesoclimate) are created and mediated by the dominance and dynamics of *Sphagnum* species. This phenomenon seems to be the basic link to the historical postglacial environment in providing a paleorefugium for survival of glacial relict biota and highly specific guilds of forest-tundra plants and stenotopic insects namely Lepidoptera (cf. e.g. PEUS, 1932; SHENNIKOV, 1953; KROGERUS, 1960; SJÖRS, 1961; POP, 1964; TALLIS, 1991; VAN BREEMEN, 1995; SPITZER & DANKS, 2006; TURLURE et al., 2010). Labrador tea (*Ledum palustre*) and its guild of herbivorous insects (Lepidoptera especially) is one of such peatland phenomena typical for some central and northeastern European bog habitats. *Ledum palustre* is a xeromorphic peat bog evergreen shrublet (Fig. 3), not really xerophytic, but rather a psychrophytic cold-adapted component of the subarctic tundra/forest-tundra zone and the peatlands of boreal and northern temperate zones (SCHIMPER, 1898; SHENNIKOV, 1953; TOLMATCHEV & JURTZEV, 1980; RYDIN & JEGLUM, 2006).

The peatland Lepidoptera associated with relict populations of *Ledum palustre* have rarely been investigated, and most scattered lepidopterological data are recorded from boreal and subarctic Europe only (e.g. KROGERUS, 1960; MIKKOLA & SPITZER, 1983; SVENSSON, 1993). Herbivorous peat bog insects like moths and butterflies are often linked obligatorily to highly specific cold-adapted food plants. *Ledum palustre* of postglacial isolated peatlands is one of the best examples under local "climatic trap" of bog edaphic climax, but has not been sufficiently investigated from an entomological point of view (but see TURLURE *et al*., 2010 for butterflies recorded from other types of western European peatlands and different food plants). The insect guilds of relict populations of *Vaccinium uliginosum* in isolated peat bogs seem to be much better known (e.g. KROGERUS, 1960; SPITZER *et al*., 2003; LOZAN *et al*., 2012). In our investigations, tyrphobiontic moths and butterflies of peat bogs are shown to be closely associated with two basic cold-adapted plants, *Ledum palustre* and *Vaccinium uliginosum* (see Table I - nine characteristic glacial relict species, five of them are strictly monophagous on *Ledum palustre*). The group of tyrphophiles and tyrphoneutrals is characteristic by much greater variety of food plants and consequently by wider ecological amplitude (cf. Table I), but are probably less cold-adapted compared to tyrphobionts (cf. SPITZER & DANKS, 2006).

The most interesting groups of species in Table I are not only the common monophagous tyrphobionts feeding on *Ledum palustre*, but those that also feed on another relict food plant, *Vaccinium uliginosum*. The group of tyrphoneutral species is more widely distributed also outside the Červené blato bog, but many species are endangered in man-made landscapes because of modern human impacts on traditional habitats (SPITZER & JAROŠ, 1993; SPITZER *et al*., 1999). From the conservation point of view, the geometrid moth *Eupithecia gelidata* Möschler, 1860 (Fig. 4 and Table I) seems to be one of the most interesting very isolated subarctic species associated with *Ledum palustre* in central Europe (see SPITZER *et al*., 1991 with conclusions accepted by MIRONOV, 2003, with his map of *E. gelidata* distribution on page 195). The Červené blato guild is nearly identical or very similar to the *Ledum*/*Vaccinium* guild in boreal and subarctic Fennoscandia. Only two Fennoscandian tyrphobiontic moths (*Coleophora obscuripalpella* Kanerva, 1941 and *Carpatolechia epomidella* (Tengström, 1869)) feeding only on *Ledum palustre* are not recorded from Červené blato or any other locality in Central Europe (see KROGERUS, 1960; MIKKOLA & SPITZER, 1983; SVENSSON,

Table I.– Lepidoptera feeding on *Ledum palustre* in the Červené blato bog, South Bohemia (Czechia). M - monophagous, O - oligophagous, P - polyphagous. * - oligophagous populations in boreal and subarctic zones of northern Europe - see SPITZER *et al*. (1991) for *E. gelidata* (Fig. 4) and SVENSSON (1993) for *L. ledi* (Fig. 5). Degree of abundance (2000-2011 years): 1-5 very rare, 6-20 rare, 21-50 common, >50 very common.

Species	**Abundance of larvae on *Ledum***	**Feeding specificity**	**Examples and numbers of other local foodplants**
TYRPHOBIONTS			
Stigmella lediella (Schleich, 1867) - Nepticulidae	common	M	none
Lyonetia ledi Wocke, 1859 - Lyonetiidae	very common	M	none*
Coleophora ledi Stainton, 1860 - Coleophoridae	common	M	none
Olethreutes ledianus (L., 1758) - Tortricidae	very common	M	none
Vacciniina optilete (Knoch, 1781) - Lycaenidae	very rare	O	*Vaccinium uliginosum*
Chloroclysta infuscata (Tengst., 1869) - Geometridae	rare	O	*Vaccinium uliginosum*
Eupithecia gelidata Möschler, 1860 - Geometridae	rare	M	none*
Arichanna melanaria (L., 1758) - Geometridae	very common	O	*Vaccinium uliginosum*
Lithophane lamda (F., 1787) - Noctuidae	very rare	O	*Vaccinium uliginosum*
TYRPHOPHILES			
Sterrhopterix fusca (Haworth, 1809) - Psychidae	rare	P	*Vaccinium* spp. + ca. 10
Rhagades pruni ([D. & S.], 1775) - Zygaenidae	rare	P	*Vaccinium* spp. + 2
Lozotaenia forsterana (F., 1781) - Tortricidae	very rare	P	*Vaccinium* spp. + ca. 5
Apotomis sauciana (Frölich, 1828) - Tortricidae	very rare	O	*Vaccinium* spp.
Lasiocampa quercus (L., 1758) - Lasiocampidae	very rare	P	*Vaccinium* spp. + ca. 5
Semiothisa brunneata (Thbg, 1784) - Geometridae	very common	P	*Vaccinium* spp. + ca. 5
Syngrapha interrogationis (L., 1758) - Noctuidae	rare	P	*Vaccinium* spp. + ca. 5
Lithomoia solidaginis (Hübner, 1803) - Noctuidae	very common	P	*Vaccinium* spp. + ca. 5
TYRPHONEUTRALS			
Canephora hirsuta (Poda, 1761) - Psychidae	very rare	P	*Vaccinium* spp. + ca. 10
Ypsolopha parenthesella (L., 1761) - Ypsolophidae	rare	P	*Vaccinium* spp. + ca. 5
Archips podanus (Scopoli, 1763) - Tortricidae	very rare	P	*Vaccinium* spp. + ca. 10
Ptycholoma lecheanum (L., 1758) - Tortricidae	very rare	P	*Vaccinium* spp. + ca. 5
Olethreutes lacunanus ([D. & S.], 1775) - Tortricidae	very rare	P	*Vaccinium* spp. + ca. 10
Orthotaenia undulana ([D. & S.], 1775) - Tortricidae	rare	P	*Vaccinium* spp. + ca. 5
Scopula ternata (Schrank, 1802) - Geometridae	very rare	P	*Vaccinium* spp. + ca. 5
Eulithis populata (L., 1758) - Geometridae	rare	P	*Vaccinium* spp. + ca. 5
Operophtera brumata (L., 1758) - Geometridae	common	P	*Vaccinium* spp. + ca. 10
Crocallis elinguaria (L., 1758) - Geometridae	very rare	P	*Vaccinium* spp. + ca. 5
Angerona prunaria (L., 1758) - Geometridae	rare	P	*Vaccinium* spp. + ca. 5
Alcis repandata (L., 1758) - Geometridae	very rare	P	*Vaccinium* spp. + ca. 10
Hypomecis punctinalis (Scop., 1763) - Geometridae	very rare	P	*Vaccinium* spp. + ca. 10
Euproctis similis (Fuessly, 1775) - Lymantriidae	very rare	P	*Vaccinium* spp. + ca. 10
Arctia caja (L., 1758) - Arctiidae	very rare	P	*Vaccinium* spp. + ca. 10
Acronicta auricoma ([D. & S.], 1775) - Noctuidae	very rare	P	*Vaccinium* spp. + ca. 10
Autographa pulchrina (Haworth, 1809) - Noctuidae	very rare	P	*Vaccinium* spp. + ca. 10
Agrochola helvola (L., 1758) - Noctuidae	very rare	P	*Vaccinium* spp. + ca. 5
Eurois occultus (L., 1758) - Noctuidae	very rare	P	*Vaccinium* spp. + ca. 10

1993; HUEMER & KARSHOLT, 1999). The southernmost records of *C. epomidella* are known from peat bogs covered by *L. palustre* shrubs in southern Lithuania near the Belarus border (DAPKUS *et al*., 2007). It seems to be evident that local moths associated with relict food plants only (*Ledum* and *Vaccinium*) are typical and common in the unique peat bog locality of Červené blato (Table 1). The most polyphagous tyrphoneutral species associated with *Ledum* are usually rare in the bog. Not only the most important "*Sphagnum* microclimate" of peat bogs, but also the highly specific chemical and physiological quality of local food plants (e.g. *Ledum palustre*, *Vaccinium uliginosum* and other *Vaccinium* spp.) are significant for survival of cold-adapted insect herbivores during the postglacial

Holocene periods in boreal and temperate Europe (cf. KROGERUS, 1960; SPITZER & JAROŠ, 1993; SPITZER & DANKS, 2006; TURLURE *et al*., 2009, 2010).

We can conclude, that the central European complex of tyrphobiontic and many tyrphophile species of Lepidoptera associated obligatorily with *Ledum palustre* and with several other related subarctic continental plants (e.g. *Vaccinium uliginosum* and other Ericaceae) have been surviving in the cold "microclimatic peat bog traps" (cf. TURLURE *et al*., 2009, 2010) during the Holocene postglacial period (with several relatively short warm periods, e.g. Epiatlanticum - cf. JANKOVSKÁ, 1980, 1995; MAUQUOY & YELOFF, 2008; QUANTE, 2010; WILLIS *et al*., 2010). In such peatland systems in central Europe, the recent possible climate change should be less important for insect survival and conservation of the local edaphic climax environment of large fragments of peat bogs and hydrological conditions, so long as they remain undisturbed by human activities (see also some ideas of TRAVIS, 2003; SWENGEL & SWENGEL, 2010; HAMPE & JUMP, 2011; LOZAN *et al*., 2012). The isolated large peat bog "island" habitats of *Ledum palustre* and associated guilds of cold-adapted moths and butterflies seem to be the best indicators for implementation of biodiversity conservation and urgent insect monitoring of the unique fragmentary southern frontiers of the boreal/subarctic zone in Europe. The other central European bogs outside the Třeboň Basin represent different peatlands without or with very rare *Ledum* shrublets and *Ledum* associated insects (SPITZER & DANKS, 2006 with bibliography; BEZDĚK *et al*., 2006; LOZAN *et al*., 1012). A unique biodiversity variation of Lepidoptera within and between the central-northern European peat bog paleorefugial sites is one of the most important conservation aspects.

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Figs. 2-5.– 2. Habitat of dominant *Ledum palustre* in the Červené blato bog (Central Europe), with visible *Pinus rotundata.* **3.** Shrublet of *Ledum palustre*, Červené blato bog. **4.** Larva of *Eupithecia gelidata* Möschler feeding on *Ledum palustre* in the Červené blato bog. Alternative food plants of *E. gelidata* in subarctic and arctic zones are *Salix* spp., not only *L. palustre*. **5.** A typical tyrphobiontic moth *Lyonetia ledi* Wocke (Červené blato bog) is recorded from Fennoscandian peatlands with an alternative food plant - *Myrica gale* L. In Central Europe the only food plant of *L. ledi* is *Ledum palustre*.